

## SINUOUS COMPOSITE CONNECTOR SYSTEM

### Background of the Invention

This invention relates generally to concrete sandwich walls and, more specifically, to  
5 concrete sandwich walls wherein the two concrete layers are tied together by a sinusoidal element  
made of fiber-reinforced composite material. The concrete sandwich walls are both stiff and  
strong while providing high thermal efficiency.

In a typical pre-cast concrete sandwich wall, a layer of insulation is placed between two  
concrete panels and the entire system is held together using some form of connecting system.  
10 Concrete sandwich wall panels are subject to lateral forces such as wind and seismic load, gravity  
loads, and temperature-induced forces. These lateral forces, as well as temperature differentials  
between the two layers of concrete induce shear forces in the connection systems as well as  
bending, shear, and axial forces in both layers of the panel.

Concrete sandwich panels are designed as composite, partially composite, or non-  
15 composite. A composite sandwich panel of a given total thickness will have nearly the same  
stiffness and strength as a solid panel of the same thickness, while a non-composite panel will  
have roughly the same stiffness and strength as the sum of the stiffness and strength values for  
the individual concrete layers comprising the wall panel. Partially composite walls will have  
stiffness and strength that are intermediate to the values for composite and non-composite panels.

20 Composite walls are normally made using a connection system of metal trusses that  
passes through the insulation. Generally made of steel, these metal trusses provide high shear  
stiffness and effectively limit differential slip between the concrete layers. These trusses,  
however, are susceptible to corrosion damage and have a very high thermal conductivity.

Sandwich panels made with these metal trusses therefore have a suspect service life and provide relatively low thermal performance.

Non-composite and partially composite wall panels are normally constructed using flexible connectors that are installed perpendicular to the plane of the insulation. Because the connectors provide low shear restraint, large differential slip between the concrete layers is possible. In the current art, partially composite panels are constructed by removing sections of insulation to provide discrete through-thickness concrete zones. These zones are normally located at the ends and at intermediate points along the length of the panel and limit the local slip between the concrete layers; however, the flexible connectors between through-thickness concrete zones will allow local slip. Although the uncracked stiffness of such panels will be nearly the same as for a composite panel, partially composite panels will tend to crack at lower loads than composite panels.

Although composite and partially composite walls are much more efficient than non-composite walls in resisting normal horizontal forces, the connection system's enforcement of strain compatibility between the concrete layers can create undesirable behaviors. The primary function of an insulated concrete sandwich panel is to provide a thermal barrier between the ambient environment and the conditioned air within the building. The thermal barrier must, therefore, lead to significant temperature differentials between the two concrete layers.

Consequently, as one concrete layer increases in temperature, it expands in the plane of the panel. The connection system and the other concrete layer eccentrically restrain this expansion, leading to "thermal bowing" of the assembly analogous to that observed with a bi-metallic strip.

Similar behavior will occur in composite or partially composite panels with different levels of prestressing between the two layers. While this can be primarily an aesthetic problem, it can also lead to failure of the sealant at the joints between panels. This effect is most dramatic at the building corners, where the differential movement is magnified by the geometry of the joint. Also, in many applications, both composite and partially composite panels have excess capacity.

In contrast to a composite wall connection system, a non-composite wall connection system allows nearly unrestrained in-plane movement of the two concrete layers. Thermal bow is minimized, and joint sealants are less likely to fail.

Each of the wall types therefore have positive and negative features. Although non-composite wall panels are generally too flexible or have insufficient strength to safely resist wind loads, many composite and partially composite wall panels have excess capacity and suffer from thermal and differential pre-stress bowing. There is a need for an intermediate, partially composite connection system for concrete sandwich panels that provides adequate resistance to lateral loads while providing reduced thermal bowing and provides a thermally efficient wall panel.

Prior art connecting systems use truss-type connectors that may be weblike, diagonal, or sinusoidal. In the prior art, these sandwich panel walls that use truss-type connectors normally use chord members, or pre-stressed rods that are welded, wrapped around, or otherwise attached to the truss-type connectors. Beyond providing anchorage of the sinuous members within the concrete, these chord members or pre-stressed rods provide little, if any, benefit as the concrete

layers themselves then act to carry longitudinal forces. The disadvantage of this system is that the concrete is must carry the forces, not the connectors.

Examples of this type of connecting system include United States Patent No. 4,236,364, describing a concrete sandwich wall panel that has a wire sinuous connecting element. This  
5 connecting element is crimped over chords or pre-stressing steel used within the concrete layers. Also, United States Patent No. 5,440,845 describes a concrete sandwich wall panel that uses a fiber composite sinuous element wound around a reinforcing rod contained within the concrete layers. United States Patent No. 6,088,985 describes a weblike truss connecting system.

#### Summary of the Invention

The present invention is an insulated concrete wall panel consisting of two layers of concrete with an insulating layer in between the concrete layers. A sinusoidal-shaped, fiber-reinforced composite element connects the two concrete layers. The connector is imbedded in the two layers of concrete and passes through the insulation layer. The connector provides the  
15 requisite transmission of forces merely by being consolidated in the concrete layers.

Therefore, a primary objective of the invention is the provision of an improved concrete sandwich wall that is stiff, strong, and thermally efficient.

Another objective of the invention is the provision of an improved connector that bears and transmits the forces within the concrete panel.

A further objective of the invention is the provision of an improved connection system for concrete sandwich walls that results in a wall that while partially composite by definition, has the characteristics and strength of a fully composite wall.

Another objective of the invention is the provision of an improved connection system for  
5 concrete sandwich walls that acts to carry longitudinal forces instead of requiring the concrete panels to bear these forces.

A further objective of the present invention is the provision of a connection system for concrete sandwich walls that requires less skill and is less expensive to construct.

Another objective of the invention is the provision of an improved connection system for  
10 concrete sandwich walls that uses connectors that are not attached to any pre-stressed reinforcing rods.

These and other objects of the present invention will become apparent to those skilled in the art upon reference to the following specification, drawings, and claims.

15 Brief Description of the Drawings

Figure 1 is a sectional view through a concrete sandwich wall panel showing the connectors in place.

Figure 2 is a sectional view through a concrete sandwich wall panel showing the assembly of the wall panel with the sinuous connecting element installed in pre-notched  
20 insulation.

Figure 3 is a perspective view of the same assembly as in Figure 2.

Figure 4 is a sectional view through a concrete sandwich wall panel showing the assembly of the wall panel with the sinuous connecting elements attached to longitudinal reinforcing elements and the insulating layers then pushed into position.

Figure 5 is a perspective view of the same assembly as in Figure 4.

5        Figure 6 is a sectional view through a concrete sandwich wall panel showing the assembly of the wall panel with the first concrete layer and insulating layer in position and the sinuous connecting elements then pushed into place.

Figure 7 is a perspective view of the same assembly as in Figure 6.

Figure 8 is...

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#### Detailed Description of the Invention

Composite sandwich wall 10 includes a first concrete layer 12 and a second concrete layer 14 with an insulating layer 16 sandwiched therebetween. Embedded in both the first concrete layer 12 and the second concrete layer 14 and extending through the insulating layer 16  
15 is a sinuous connecting element 18.

The sinuous connecting element 18 is composed of fiber reinforced composite material formed during linear, prismatic, thermoplastic pultrusion. The preferred method of bending the fiber-reinforced composite material into sinusoidal form uses microwave energy directed at discrete locations along the length of the linear pultrusion, as described in United States Patent  
20 Application No. 60/397,551 (incorporated herein by reference).

The fibers within the sinuous connecting element 18 must remain the same length during the bending process. Accordingly, the fibers on the outside of the bend must move laterally to maintain nearly the same length on the inside of the bend, while the fibers on the inside of the bend must have a bend shorter radius to maintain the same length. When cooled, the bends and deviations are locked into sinusoidal form. When installed within concrete, these local deformations help to provide anchorage of the sinuous connecting element 18 to the concrete by forcing radial stresses in the surrounding concrete. An additional source of anchorage, which is a direct function of the bend radius and the bending capacity of the element, is found using virtual work. If a force,  $P$ , is sufficient to pull the bent profile through a virtual displacement,  $\delta$ , then the external virtual work =  $P \delta$ . The internal virtual work =  $2M \delta/R$ , where  $R$  = the bend radius of the profile and  $M$  = the bending capacity of the profile. Therefore,  $P=2M/R$ . The anchorage of the wire is therefore at least partially dependent on maintaining a bending resistance within the connector profile.

In one embodiment, as shown in Figures 2-3, the insulating layer 16 is pre-machined and rigid. The sinuous connecting element 18 is installed at the edges of the insulating layer 16. The combined insulating layer 16 and sinuous connecting element 18 are then installed in a concrete panel by placing the combination in the first concrete layer 12 and then placing the second concrete layer 14 on the insulating layer 16.

In a second embodiment, as shown in Figures 4-5, sinuous connecting elements 18 are attached to longitudinal reinforcing strands 20 that are located near the center of the future concrete layers. The sinuous connecting elements 18 are attached in such a manner that they

extend approximately equal distances from the centerline of the future insulating layer. This attachment can be effected using wire ties or plastic clips that bind the sinuous connecting elements 18 to the longitudinal reinforcing strands 20. Multiple sinuous connecting elements 18 are installed across the width and the length of the form. A first layer of concrete 12 is placed in the form, and a relatively flexible insulating layer 16 is placed between the sinuous connecting elements 18. The second layer of concrete 14 is then placed. In this embodiment, the insulating layer 16 is flexible and resilient so as to be capable of deforming at the sinuous connecting elements 18 to form a seal around the elements and to provide a continuous thermal break over the full panel area.

In a third embodiment, as seen in Figures 6-7, the order of the installation is altered. Initially, the longitudinal reinforcing strands 20 are in place in the first concrete layer 12 or both the first concrete layer 12 and the second concrete layer 14. After the first concrete layer 12 is placed in the form, flexible and resilient insulating strips 16 are installed. The sinuous connecting elements 18 are then pushed through the joints between the insulating strips 16. This may require that the form or the sinuous connecting elements 18 be vibrated during installation to allow the element to be pushed into the plastic concrete in the first layer of concrete 12. The sinuous connecting elements 18 will have depth indicators to allow the installers to gauge the depth of insertion of the elements. After insertion to the correct depth, the resilient insulating layer 16 will hold the elements at the proper depth while the second layer of concrete 14 is placed. This method is an advantage over existing methods in that the widths of the insulation

strips do not require coordination with the location of the reinforcing elements in either concrete layer.

5 With the sinuous connecting elements of the present invention, a concrete sandwich wall has a substantially composite nature, as the connectors enhance the transfer of forces between the concrete layers while also eliminating or minimizing thermal transfer or bridging between the concrete layers. This connecting system is in no way attached to any chord elements or pre-stressed rods; instead, the connecting elements themselves are firmly anchored in the concrete and bear the forces. The concrete itself acts as the chord elements of a truss, eliminating the need for attachment to pre-stressed rods or chords. The sinuous connecting elements themselves carry  
10 the longitudinal forces.

The preferred embodiment of the present invention has been set forth in the drawings, specification, and although specific terms were employed, these are used in a generic or descriptive sense only and are not used for purposes of limitation. Changes in the form and proportion of parts as well as in the substitution of equivalents are contemplated as circumstances  
15 may suggest or render expedient without departing from the spirit and scope of the invention as further defined in the following claims.